Structural Analysis of the Drivers of AI-Based Sustainability Reporting in Iran

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Abstract: The application of artificial intelligence (AI) in sustainability reporting requires not only technological capabilities but also an understanding of institutional requirements and conditions for organizational adoption. The present study aimed to identify, classify, and prioritize the drivers of AI-based sustainability reporting in Iran. In terms of purpose, the study was developmental; in terms of data collection, it was descriptive and non-experimental; and in terms of orientation, it was exploratory. The methodological approach was based on integrating qualitative analysis of relevant sources with the quantitative assessment of expert judgments. First, 36 preliminary drivers were extracted through environmental scanning and content analysis of scientific documents. The list of factors was subsequently refined through three Delphi rounds with the participation of 15 experts selected using judgmental purposive and snowball sampling. The criterion for retaining factors was a minimum mean score of 3.50 on a five-point scale. Following a comparison of eight classification frameworks, the PESTLE framework was selected, and the importance and uncertainty of the retained drivers were assessed on five-point and ten-point scales, respectively. The findings showed that 24 drivers were retained, while Kendall's coefficient of concordance increased from 0.322 in the first round to 0.546 in the third round. The drivers were classified into technological, economic, legal, political, and social dimensions, with frequencies of 7, 6, 5, 3, and 3, respectively. By simultaneously applying an importance threshold of 4.5 and an uncertainty threshold of 6.5, seven key drivers were identified: algorithmic advances; predictive and analytics-oriented reporting; full transparency and traceability; evolution of sustainability reporting standards; mandatory national and international regulations; the role of regulatory and professional institutions; and intra-organizational readiness and resistance. Regulations and standards exhibited the highest levels of uncertainty, with scores of 9.07 and 8.20, respectively. The results underscore the need to coordinate technological development with standard-setting, professional oversight, and enhanced organizational readiness. The resulting framework provides a basis for prioritizing policies, investments, and capacity-building programs aimed at advancing intelligent sustainability reporting.

Keywords: sustainability reporting, artificial intelligence, key drivers, Delphi method, importance–uncertainty.

1. Introduction

Sustainability reporting has evolved from a largely voluntary communication practice into an increasingly important component of corporate accountability, strategic management, stakeholder engagement, and long-term value creation. Organizations are now expected to disclose not only conventional financial information but also environmental, social, governance, and broader sustainability-related information that enables stakeholders to evaluate corporate performance from a multidimensional perspective. This development reflects the growing recognition that organizational success cannot be adequately assessed solely through short-term financial outcomes, because firms operate within complex economic, social, institutional, and ecological systems whose

conditions directly affect organizational resilience and legitimacy. Sustainability reporting therefore functions as both an external disclosure mechanism and an internal management process through which organizations define priorities, identify material issues, monitor performance, and communicate progress. Earlier research has shown that the scope, quality, and content of sustainability reports vary substantially across organizations and that reporting practices are influenced by organizational characteristics, stakeholder expectations, sectoral conditions, governance arrangements, and institutional pressures [1, 2]. From an integrated business perspective, sustainability reporting is also closely linked to broader efforts to incorporate sustainability into organizational strategy and performance-management systems rather than treating it as a peripheral communication activity [3, 4].

The strategic importance of sustainability reporting has increased further with the emergence of the Sustainable Development Goals, expanding regulatory expectations, stronger demands for transparency, and the increasing need for assurance over nonfinancial information. Organizations are under growing pressure to demonstrate how their operations contribute to or affect sustainable development while providing decision-useful information to investors, regulators, customers, employees, civil society organizations, and other stakeholders. Sustainability reporting and assurance are consequently becoming more closely connected to organizational accountability and the measurement of progress toward sustainable development objectives [5]. Empirical evidence also indicates that organizations differ in the speed and extent with which they adopt sustainability-oriented reporting frameworks, and that early adoption is associated with particular organizational conditions and strategic orientations [6]. At the same time, the development of sustainability reporting is not simply a technical issue of selecting indicators and preparing disclosures. It involves organizational learning, internal coordination, changes in processes and responsibilities, and the integration of sustainability considerations into decision-making structures. Research on the relationship between sustainability reporting and organizational change has emphasized that reporting processes can both reflect and stimulate broader transformations in organizational practices [7, 8].

Despite this progress, sustainability reporting continues to face significant challenges concerning data availability, comparability, reliability, consistency, timeliness, materiality, and the credibility of reported information. Traditional reporting systems often depend on fragmented databases, manual data collection, retrospective indicators, heterogeneous measurement procedures, and significant professional judgment. These characteristics can increase reporting costs and create limitations in the speed, precision, and analytical depth of sustainability disclosures. Moreover, as sustainability reporting expands to include increasingly complex environmental, social, and governance indicators, organizations must process large volumes of structured and unstructured information derived from multiple internal and external sources. The complexity of these requirements is particularly evident in studies examining sustainability indicators, which show considerable diversity in the metrics disclosed by organizations and in the manner in which sustainability performance is operationalized [2]. Similarly, the integration of sustainability performance into business systems requires mechanisms capable of linking diverse measures, strategic objectives, operational activities, and decision-making processes [4]. These challenges create a strong rationale for the adoption of advanced digital technologies capable of improving data processing, analytical capability, and the responsiveness of reporting systems.

Artificial intelligence represents one of the most significant technological developments with the potential to reshape sustainability accounting and reporting. AI-based systems can contribute to automated data collection, anomaly detection, pattern recognition, predictive modeling, natural language processing, classification, real-time analysis, and the integration of large and heterogeneous datasets. In financial reporting, recent research suggests that AI integration can influence reporting quality by increasing the efficiency of information processing and

strengthening analytical capabilities, although the magnitude and direction of such effects depend on the organizational and institutional context in which AI is implemented [9]. Within sustainability reporting, digital technologies can similarly enhance the ability of organizations to manage complex sustainability information, improve the timeliness of disclosures, and support more sophisticated forms of sustainability accounting [10, 11]. The transition associated with Industry 4.0 has intensified this transformation by increasing connectivity, automation, data availability, and the use of intelligent technologies in organizational processes, thereby creating new possibilities for sustainability measurement and reporting [11].

The potential contribution of AI to sustainability, however, extends beyond process automation. AI can alter the underlying logic of sustainability reporting by shifting reporting systems from static, periodic, and predominantly retrospective disclosure toward more dynamic, predictive, and analytically enriched forms of information production. Such systems may enable organizations to identify emerging sustainability risks, forecast performance trajectories, detect inconsistencies in reported information, analyze stakeholder sentiment, and support managerial decisions with greater speed and granularity. From a broader sustainability perspective, AI has been identified as a technology with substantial potential to contribute to environmental and social goals, although its implementation also creates new ethical, organizational, governance, and resource-related challenges [12]. Accordingly, the relationship between AI and sustainability should not be interpreted as inherently positive; instead, its outcomes depend on the manner in which technological capabilities are designed, governed, and embedded within organizational systems. This point is particularly important in sustainability reporting because the use of AI can improve information quality while simultaneously creating risks related to opacity, algorithmic bias, data privacy, accountability, and excessive reliance on automated outputs.

The increasing use of AI also raises important questions about the transparency of AI itself. Organizations adopting AI-based systems may need to disclose how these technologies are used, what types of data they process, how algorithmic decisions are governed, and what controls are implemented to manage associated risks. Research examining AI disclosures in sustainability reports has therefore emphasized the need for a more systematic reporting framework through which firms can communicate their use of artificial intelligence and its sustainability implications [13]. At the same time, the rapid expansion of sustainability claims creates the risk that advanced digital technologies may be used not only to improve transparency but also to produce more sophisticated forms of selective disclosure or greenwashing. The relationship among AI, sustainability reporting, and greenwashing has consequently become an important area of inquiry, particularly because AI can both help identify misleading sustainability claims and, if poorly governed, contribute to producing or amplifying them [14]. These dual possibilities reinforce the importance of governance frameworks, professional oversight, assurance mechanisms, data integrity, and regulatory requirements in determining whether AI strengthens or undermines the credibility of sustainability reporting.

The quality of sustainability reporting is also strongly influenced by governance and organizational characteristics. Evidence from corporate groups indicates that corporate governance arrangements can significantly affect sustainability reporting quality, suggesting that technological adoption cannot be considered independently of governance structures and accountability mechanisms [15]. Similarly, managerial perceptions of the drivers and barriers to corporate social responsibility demonstrate that organizational decisions concerning sustainability are shaped by multiple internal and external pressures rather than by a single economic or technological factor [16]. Organizational capabilities and industry structure can further affect the extent to which firms engage in social responsibility activities and, by implication, their ability to generate and disclose sustainability-related information

[17]. These findings indicate that the implementation of AI-based sustainability reporting should be approached as a socio-technical and institutional transformation involving technology, managerial readiness, governance, stakeholder pressures, professional standards, and organizational resources.

Internal organizational conditions are especially important because even technically advanced reporting systems are unlikely to produce meaningful results without appropriate human competencies, structures, incentives, and organizational readiness. Prior research in Iran has found that internal organizational factors can influence sustainability reporting practices among listed companies, highlighting the importance of firm-level capabilities and managerial conditions in the development of sustainability disclosures [18]. Other Iranian studies have shown that ownership structure, corporate governance, and organizational characteristics are relevant to the development of sustainability and voluntary disclosure practices [19, 20]. These findings are consistent with the broader literature emphasizing the relationship between sustainability reporting and organizational change [7, 8]. They also suggest that resistance to technological change, insufficient skills, lack of cross-functional coordination, and inadequate organizational infrastructure may constitute barriers to the adoption of AI-based reporting even when the technology itself is available.

In the Iranian context, the need to strengthen sustainability reporting has been recognized for more than a decade, particularly in relation to financial markets, corporate transparency, and the information needs of stakeholders [21]. Iranian scholarship has also contributed to the conceptual development of sustainability reporting by explaining its theoretical foundations and its relationship with corporate accountability and disclosure [22]. Empirical studies have examined determinants of corporate social responsibility disclosure and have used analytical techniques such as data mining to identify and rank influential factors, indicating that sustainability disclosure is shaped by a complex set of interacting organizational and contextual variables [23]. At the same time, the Iranian business environment has particular institutional, regulatory, technological, and economic characteristics that can influence both the adoption of sustainability reporting and the implementation of AI. These conditions make direct transplantation of findings from developed markets potentially inadequate and increase the importance of identifying drivers that are specifically relevant to the Iranian context.

The institutional dimension is particularly significant because sustainability reporting develops within a network of regulatory agencies, professional bodies, capital-market institutions, accounting standards, corporate governance mechanisms, government policies, and stakeholder expectations. International evidence demonstrates that progress in sustainability reporting is often associated with coordinated institutional initiatives, professional guidance, and the gradual development of reporting practices rather than with isolated organizational action [24]. In this regard, the evolution of mandatory reporting requirements and sustainability standards may substantially influence the willingness and capacity of firms to invest in AI-based reporting systems. At the same time, uncertainty surrounding regulatory development can complicate technological investment decisions because organizations may be reluctant to build information systems around standards that remain subject to rapid change. Thus, the interaction between technological advances and the legal-regulatory environment is likely to represent a major source of both opportunity and uncertainty in the future development of AI-based sustainability reporting.

Economic factors are likewise important. Implementing AI-based reporting systems requires investments in data infrastructure, software, cybersecurity, employee training, system integration, and specialized expertise. Organizations must therefore assess the expected benefits of such investments against their costs and strategic risks. The business case for sustainability-related investments depends partly on stakeholder demand, capital-market incentives, access to finance, competitive pressures, and the extent to which sustainability performance is connected

to organizational value creation [3]. As sustainability information becomes increasingly relevant to investors and other market participants, firms may face stronger incentives to develop technologically advanced reporting capabilities. However, the economic attractiveness of such systems may vary across organizations according to firm size, industry, ownership structure, resources, and exposure to international supply chains. Iranian evidence concerning the relationship between ownership structures, governance, and sustainability disclosure further demonstrates that firms are unlikely to respond uniformly to such incentives [19, 20].

The social and human dimensions of technological transformation should also not be overlooked. AI-based reporting involves changes in professional roles, work processes, decision authority, and the interaction between human judgment and automated systems. Employees may perceive such changes as opportunities for improved productivity and analytical capability or as threats to established routines, professional autonomy, and job security. The quality of organizational environments can affect employee adaptation, performance, and acceptance of technological and structural change, making the human context relevant to successful implementation [25]. Organizational readiness for AI-based sustainability reporting therefore includes not only technical infrastructure but also employee capabilities, managerial support, communication, training, and the management of resistance. These factors are particularly relevant where new reporting systems require cooperation among accounting, information technology, sustainability, audit, risk management, and executive functions.

Taken together, prior studies provide substantial knowledge about the determinants of sustainability reporting, organizational sustainability, digital transformation, AI applications, corporate governance, disclosure quality, and organizational change. Nevertheless, these streams of literature remain relatively fragmented. Research on sustainability reporting has often focused on determinants of disclosure or reporting quality [1, 15], while AI research has frequently emphasized technological opportunities and challenges [9, 12]. Other studies have addressed digital technologies in sustainability accounting [10, 11], AI disclosure itself [13], or the potential relationship between AI and greenwashing [14]. Although these contributions are important, less attention has been devoted to systematically identifying the broader technological, economic, political, legal, and social drivers that jointly shape the development of AI-based sustainability reporting, especially in emerging institutional environments such as Iran.

This gap is particularly important from a futures-oriented management perspective. The implementation of AI-based sustainability reporting is unlikely to be determined by a single dominant factor; rather, it will depend on the interaction of technological maturity, reporting standards, regulatory requirements, professional institutions, stakeholder pressure, organizational readiness, economic incentives, and broader governance conditions. Because some of these drivers may be both highly important and highly uncertain, managers and policymakers require more than a simple list of influential factors. They need a structured understanding of which drivers should receive priority attention, which factors may generate the greatest uncertainty, and how the drivers are distributed across different dimensions of the organizational environment. Such an understanding can support strategic planning, investment prioritization, regulatory development, professional capacity building, and the design of organizational transformation programs. The literature on sustainability reporting and organizational change reinforces the importance of adopting a systemic approach rather than treating reporting as an isolated disclosure function [7, 8], while the literature on sustainability and AI similarly emphasizes the need to consider governance and contextual conditions alongside technological capabilities [12, 14].

Accordingly, the aim of the present study is to identify, classify, and prioritize the key drivers of AI-based sustainability reporting in Iran and to determine the drivers characterized by simultaneously high importance and high uncertainty.

2. Methods and Materials

The present study is developmental in terms of purpose, descriptive and non-experimental in terms of data collection, and exploratory in terms of orientation. Its methodological framework is based on integrating qualitative analysis of relevant sources and expert judgments with quantitative analysis of the relationships among the drivers. The scope of the study is AI-based sustainability reporting in Iran, with a focus on identifying influential factors and explaining the structure of their influence and dependence. Data collection was organized in two documentary and expert-based stages. In the first stage, environmental scanning and content analysis of scientific sources and specialized reports were used as the basis for extracting the preliminary list of drivers, and the information was recorded using researcher-developed checklists and forms. In the second stage, this list was reviewed and refined through interviews, open-ended questionnaires, and the Delphi method, with the participation of accounting academics, accounting and auditing managers, and specialists in AI-based sustainability reporting. Expert assessments served as the basis for adapting the drivers to the Iranian context, classifying the factors, and determining their priorities. Structural analysis of the drivers was based on a cross-impact matrix. To construct this matrix, experts' assessments of the influence of each factor on the other factors were collected using a specialized questionnaire. Subsequently, MICMAC software was used to analyze relationships at both direct and indirect levels. Direct effects were derived from the initial matrix, whereas indirect effects were obtained from successive powers of the matrix and intermediary pathways among the factors. Comparing the results at these two levels provided the basis for determining the influence power, dependence level, and structural position of the key drivers within AI-based sustainability reporting.

3. Findings and Results

Environmental scanning and analysis of the content of scientific documents resulted in the identification of more than 71 major and subsidiary themes associated with the drivers of AI-based sustainability reporting. After eliminating duplicate items and integrating conceptually similar themes, an initial list comprising 36 drivers was developed. This list encompassed a range of technological capabilities, characteristics of reported information, legal requirements, the role of professional institutions, economic mechanisms, and conditions for organizational adoption and was used as the basis for expert evaluation. To refine and contextualize the drivers, a panel of 15 specialists was formed. Participants were selected through a combination of judgmental purposive and snowball sampling based on relevant academic and research experience, practical experience with reporting systems, and familiarity with developments in technology and sustainability. The panel consisted of 10 men and 5 women. In terms of age, 5 participants were aged 30–39 years, 8 were aged 40–49 years, and 2 were aged 50 years or older. In addition, 12 participants held doctoral degrees and 3 held master's degrees. In terms of field of specialization, accounting accounted for the largest share with 9 participants; information technology was represented by 2 participants; and economics, management, technology management, and financial management were each represented by 1 participant. Regarding occupational domain, 7 participants were engaged in academia and research, 3 in industry or private companies, 3 in independent consulting, and 2 in professional or governmental

institutions. Twelve participants reported a high or very high level of familiarity with sustainability, while 10 reported a high or very high level of familiarity with artificial intelligence. This composition enabled the incorporation of academic, practical, technological, and professional perspectives on the drivers.

Table 1. Demographic and Professional Characteristics of the Study Experts

Variable	Group	Frequency	Percentage
Gender	Female	5	33.3
	Male	10	66.7
Age	30–39 years	5	33.3
	40–49 years	8	53.3
	50 years and older	2	13.3
Education	Master's degree	3	20.0
	Doctoral degree	12	80.0
Field of specialization	Accounting	9	60.0
	Information technology	2	13.3
	Economics	1	6.7
	Management	1	6.7
	Technology management	1	6.7
	Financial management	1	6.7
Occupational domain	Academia and research	7	46.7
	Industry and private companies	3	20.0
	Independent consulting	3	20.0
	Professional or governmental institutions	2	13.3
Familiarity with sustainability	Very high	2	13.3
	High	10	66.7
	Moderate	3	20.0
Familiarity with artificial intelligence	Very high	3	20.0
	High	7	46.7
	Moderate	5	33.3

The preliminary list was refined through three Delphi rounds. In the first round, the mean scores assigned to the drivers ranged from 2.600 for "business cultural norms and level of transparency" to 4.200 for "algorithmic advances." Kendall's coefficient of concordance was 0.322, with a significance level below 0.001. Because the coefficient was below the threshold of 0.50 established in the study, the results of this round were returned to the panel members for reconsideration.

In the second round, the experts revised their assessments based on feedback regarding the means and dispersion of responses obtained in the first round. Kendall's coefficient of concordance increased to 0.494, while the significance level remained below 0.001. At this stage, "carbon pricing models and market mechanisms," with a mean score of 4.533, received the highest rating. The increase in Kendall's coefficient relative to the first round indicated greater convergence in the evaluations; however, the coefficient remained slightly below the predetermined threshold, and the process therefore continued to a third round. In the third round, Kendall's coefficient of concordance reached 0.546, with a significance level below 0.001. Accordingly, the consensus criterion defined in the study was achieved, and the assessments obtained in this stage served as the basis for the final decision regarding the retention or elimination of the factors. Distinguishing between the magnitude of the coefficient and its significance level is important in this context: statistical significance indicates the existence of concordance, whereas the magnitude of the coefficient represents the strength of that concordance.

Table 2. Trend in Expert Evaluation Concordance Across the Three Rounds of Driver Refinement

Delphi Round	Kendall's Coefficient of Concordance	Significance Level	Decision Relative to the 0.50 Threshold
First	0.322	< 0.001	Continue evaluation
Second	0.494	< 0.001	Continue evaluation
Third	0.546	< 0.001	Final evaluations stabilized

A mean score of 3.50 on the five-point scale was applied as the acceptance threshold for the drivers. At the end of the third round, 24 drivers had mean scores equal to or greater than this value and were retained, whereas 12 drivers with mean scores below 3.50 were excluded from the final list. Among the retained factors, "carbon pricing models and market mechanisms," with a mean of 4.67, received the highest score, followed by "data security, privacy, and integrity," with a mean of 4.47. The lowest mean among the retained factors was 3.87 for "credibility and reliability of information."

Table 3. Results of the Three Delphi Rounds and Final Decisions Regarding the Drivers of AI-Based Sustainability Reporting

No.	Driver	Round 1 Mean	Round 2 Mean	Round 3 Mean	Round 3 SD	Decision
1	Algorithmic advances	4.200	4.267	4.33	0.49	Retained
2	Data integration capabilities	3.000	3.267	3.27	0.46	Excluded
3	Maturity of middleware technologies	3.133	3.400	3.33	0.49	Excluded
4	Data security, privacy, and integrity	4.067	4.400	4.47	0.52	Retained
5	Accessibility and scalability	3.800	4.133	4.20	0.41	Retained
6	Complementary emerging technologies	3.067	3.333	3.33	0.49	Excluded
7	Evolution of sustainability reporting standards	3.867	4.133	4.20	0.41	Retained
8	Mandatory national and international regulations	3.733	4.267	4.33	0.49	Retained
9	AI ethics and governance frameworks	3.533	4.200	4.27	0.59	Retained
10	Role of regulatory and professional institutions	3.467	3.933	4.07	0.59	Retained
11	Government policies and incentives	4.067	4.333	4.40	0.51	Retained
12	Legal responsibility and accountability	4.067	4.333	4.40	0.51	Retained
13	Predictive and analytics-oriented reporting	3.600	3.933	4.07	0.46	Retained
14	Personalization and information relevance	3.600	3.867	4.07	0.26	Retained
15	Full transparency and traceability	3.600	3.867	3.93	0.59	Retained
16	Credibility and reliability of information	3.533	3.800	3.87	0.35	Retained
17	Real-time reporting	2.933	3.267	3.33	0.49	Excluded
18	Innovative metrics and indicators	3.667	3.933	4.13	0.35	Retained
19	Investor demand and sophistication	3.667	4.000	4.20	0.41	Retained
20	Civil society and media activism	3.800	4.267	4.27	0.46	Retained
21	Customer awareness and engagement	3.933	4.267	4.27	0.46	Retained
22	Intra-organizational readiness and resistance	4.000	4.333	4.33	0.49	Retained
23	Industry competition and collaboration	3.133	3.400	3.40	0.51	Excluded
24	Role of universities and research centers	2.667	3.133	3.13	0.35	Excluded
25	Costs and return on investment	3.867	4.333	4.33	0.49	Retained
26	Access to capital and sustainability premiums	3.933	4.267	4.27	0.46	Retained
27	Growth of sustainability data and service markets	2.800	3.067	3.20	0.41	Excluded
28	Carbon pricing models and market mechanisms	4.067	4.533	4.67	0.49	Retained
29	Compliance with global supply-chain requirements	3.933	4.333	4.40	0.51	Retained
30	International competitiveness	4.133	4.400	4.40	0.51	Retained
31	Governance challenges and institutional quality	3.667	4.133	4.20	0.41	Retained
32	National development priorities and macro-level policies	2.733	3.133	3.27	0.46	Excluded

33	Constraints on access to advanced technologies	2.867	3.200	3.40	0.51	Excluded
34	Digital divide and infrastructure readiness	2.933	3.133	3.20	0.56	Excluded
35	Capital-market maturity and local stakeholder expectations	2.667	3.067	3.20	0.41	Excluded
36	Business cultural norms and level of transparency	2.600	3.200	3.40	0.51	Excluded

The exclusion of 12 factors does not demonstrate that they are ineffective; rather, it indicates that these factors did not achieve the minimum mean score required for inclusion in the selected list during the refinement stage. By contrast, the 24 retained factors constituted the basis for subsequent classification and importance–uncertainty assessment.

To organize the selected drivers, eight classification frameworks were compared based on three criteria: "comprehensiveness in covering relevant dimensions," "fit with the research topic," and "applicability in futures studies." The evaluation was conducted on a scale from 0 to 5, with equal weights assigned to all criteria. The PESTLE model received scores of 4.4, 4.5, and 4.3 on the three criteria, respectively, resulting in an overall mean of 4.4, the highest among the frameworks examined. The STEEPLED model ranked second, with a mean score of 4.2. Accordingly, PESTLE was selected as the framework for classifying the drivers. This comparison was based on experts' descriptive ratings, and no inferential test of differences among the models was reported in the study file.

Table 4. Evaluation of Driver Classification Frameworks Based on Expert Judgments

Framework	Comprehensiveness	Fit With the Topic	Applicability in Futures Studies	Reported Mean
Sustainability Reporting Model	3.4	3.7	3.2	3.4
DEGEST	3.8	3.7	3.8	3.8
STEEPV	4.0	4.1	4.0	4.0
PEST	3.2	3.3	3.6	3.4
PESTLE	4.4	4.5	4.3	4.4
STEEPLED	4.3	4.2	4.1	4.2
STEEP	3.9	3.9	4.0	4.0
EPISTLU	3.7	3.6	3.8	3.7

The initial classification of the 24 drivers was conducted during a meeting attended by three experts and was subsequently presented to the entire panel for evaluation of the correspondence between the factors and their assigned categories. This stage was conducted in two Delphi rounds. Kendall's coefficient of concordance increased from 0.410 in the first round to 0.519 in the second round, and both tests were statistically significant at a level below 0.001. In the second round, the mean evaluations of the correspondence between the drivers and their assigned categories ranged from 4.00 to 5.00. "Legal responsibility and accountability," "personalization and information relevance," "innovative metrics and indicators," "costs and return on investment," and "governance challenges and institutional quality" each achieved a mean of 5.00 and a standard deviation of zero. In addition, the assessments of "AI ethics and governance frameworks" and "full transparency and traceability" reached a mean of 4.00 and a standard deviation of zero in the second round. These results indicate convergence in expert assessments regarding the categories assigned to these factors.

Table 5. Assessment of the Correspondence Between the Selected Drivers and PESTLE Dimensions

No.	Category	Driver	Round 1 Mean	Round 1 SD	Round 2 Mean	Round 2 SD
1	Technological	Algorithmic advances	4.67	0.488	4.73	0.458
2	Technological	Data security, privacy, and integrity	4.60	0.507	4.67	0.488
3	Technological	Accessibility and scalability	4.67	0.488	4.73	0.458

4	Legal	Evolution of sustainability reporting standards	4.73	0.594	4.87	0.352
5	Legal	Mandatory national and international regulations	4.80	0.414	4.93	0.258
6	Legal	AI ethics and governance frameworks	3.87	0.352	4.00	0.000
7	Political	Role of regulatory and professional institutions	4.93	0.258	4.93	0.258
8	Political	Government policies and incentives	4.87	0.352	4.93	0.258
9	Legal	Legal responsibility and accountability	4.93	0.258	5.00	0.000
10	Technological	Predictive and analytics-oriented reporting	4.73	0.458	4.80	0.414
11	Technological	Personalization and information relevance	5.00	0.000	5.00	0.000
12	Technological	Full transparency and traceability	3.93	0.258	4.00	0.000
13	Technological	Credibility and reliability of information	4.87	0.352	4.93	0.258
14	Legal	Innovative metrics and indicators	5.00	0.000	5.00	0.000
15	Economic	Investor demand and sophistication	4.73	0.458	4.73	0.458
16	Social	Civil society and media activism	4.87	0.352	4.93	0.258
17	Social	Customer awareness and engagement	4.07	0.258	4.07	0.258
18	Social	Intra-organizational readiness and resistance	4.87	0.352	4.93	0.258
19	Economic	Costs and return on investment	4.93	0.258	5.00	0.000
20	Economic	Access to capital and sustainability premiums	4.67	0.488	4.67	0.488
21	Economic	Carbon pricing models and market mechanisms	4.80	0.414	4.93	0.258
22	Economic	Compliance with global supply-chain requirements	4.67	0.488	4.67	0.488
23	Economic	International competitiveness	4.87	0.352	4.93	0.258
24	Political	Governance challenges and institutional quality	4.87	0.352	5.00	0.000
	Kendall's concordance	Coefficient	0.410		0.519	
		p-value	< 0.001		< 0.001	

In the final classification, 7 drivers were assigned to the technological dimension, 6 to the economic dimension, 5 to the legal dimension, and 3 each to the political and social dimensions. These dimensions accounted for 29.2%, 25.0%, 20.8%, 12.5%, and 12.5% of the selected list, respectively. In the final classification, no independent factor was assigned to the environmental dimension.

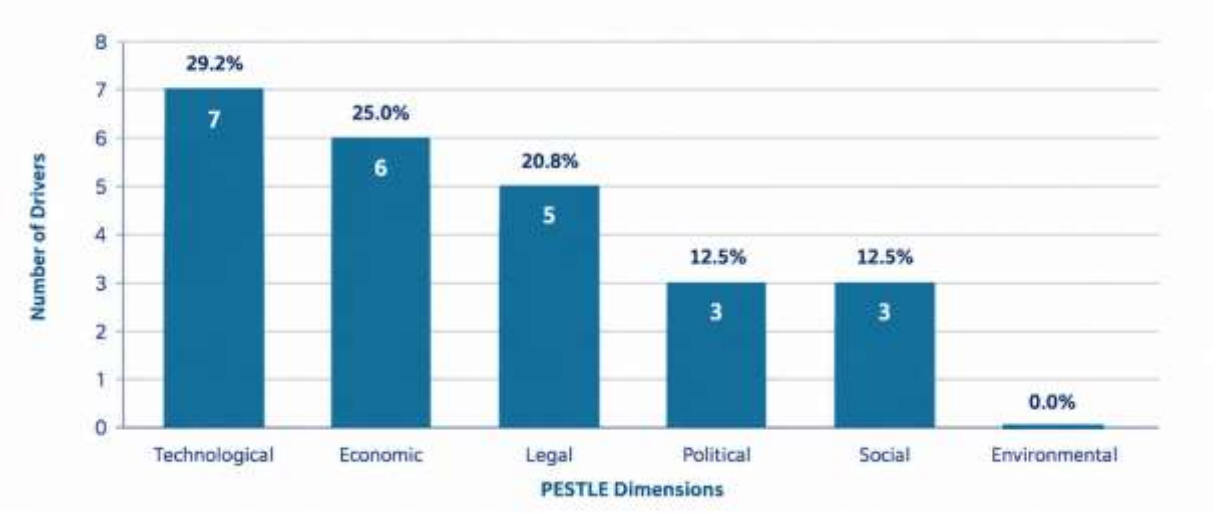


Figure 1. Distribution of the Selected Drivers Across the PESTLE Dimensions

Following finalization of the contextualized list, the importance and uncertainty of each driver were evaluated independently. Importance was assessed using a five-point scale, whereas uncertainty was measured on a scale ranging from 1 to 10. The mean importance scores ranged from 3.67 to 5.00, and the mean uncertainty scores ranged from 4.40 to 9.07. "Algorithmic advances" and "the role of regulatory and professional institutions," each with an importance score of 5.00, received the highest importance ratings; "investor demand and sophistication," with an importance score of 4.93, was also rated highly. Regarding uncertainty, "mandatory national and international regulations," with a score of 9.07; "evolution of sustainability reporting standards," with a score of 8.20; and "AI ethics and governance frameworks," with a score of 7.80, received the highest ratings.

Table 6. Importance and Uncertainty of the Selected Drivers of AI-Based Sustainability Reporting

Code	Category	Driver	Importance	Uncertainty	Reported Total
D01	Technological	Algorithmic advances	5.00	7.73	12.73
D02	Technological	Data security, privacy, and integrity	4.67	6.07	10.73
D03	Technological	Accessibility and scalability	3.87	5.07	8.93
D04	Legal	Evolution of sustainability reporting standards	4.60	8.20	12.80
D05	Legal	Mandatory national and international regulations	4.67	9.07	13.73
D06	Legal	AI ethics and governance frameworks	4.07	7.80	11.87
D07	Political	Role of regulatory and professional institutions	5.00	7.07	12.07
D08	Political	Government policies and incentives	4.13	5.80	9.93
D09	Legal	Legal responsibility and accountability	4.07	7.13	11.20
D10	Technological	Predictive and analytics-oriented reporting	4.80	7.07	11.87
D11	Technological	Personalization and information relevance	4.00	6.27	10.27
D12	Technological	Full transparency and traceability	4.73	6.93	11.67
D13	Technological	Credibility and reliability of information	4.73	5.80	10.53
D14	Legal	Innovative metrics and indicators	3.67	6.27	9.93
D15	Economic	Investor demand and sophistication	4.93	4.60	9.53
D16	Social	Civil society and media activism	4.20	6.33	10.53
D17	Social	Customer awareness and engagement	3.73	4.40	8.13
D18	Social	Intra-organizational readiness and resistance	4.73	6.87	11.60
D19	Economic	Costs and return on investment	4.00	6.20	10.20
D20	Economic	Access to capital and sustainability premiums	4.00	7.40	11.40
D21	Economic	Carbon pricing models and market mechanisms	4.00	7.73	11.73
D22	Economic	Compliance with global supply-chain requirements	4.73	6.00	10.73
D23	Economic	International competitiveness	3.87	7.47	11.33
D24	Political	Governance challenges and institutional quality	4.07	7.13	11.20

Based on the reported total scores, "mandatory national and international regulations," with a score of 13.73; "evolution of sustainability reporting standards," with a score of 12.80; and "algorithmic advances," with a score of 12.73, achieved the highest values. Nevertheless, the total scores should be interpreted in conjunction with their two independent components because a high total does not necessarily indicate that both the high-importance and high-uncertainty criteria have been satisfied simultaneously. For example, "AI ethics and governance frameworks" and "predictive and analytics-oriented reporting" have the same total score of 11.87, but their importance scores are 4.07 and 4.80, respectively. Similarly, "investor demand and sophistication," with an importance score of 4.93 and an uncertainty score of 4.60, represents a highly important factor with comparatively lower uncertainty. Conversely, "international competitiveness," with an importance score of 3.87 and an uncertainty score of 7.47, represents a factor characterized by high uncertainty but an importance score below the selection threshold. These

differences indicate that interpreting the factors on the basis of their two-dimensional positions provides more precise information than merely ranking them according to their aggregate scores.

To select the key drivers, two simultaneous conditions were applied: an importance score equal to or greater than 4.5 and an uncertainty score equal to or greater than 6.5. Accordingly, seven factors were located in the high-importance/high-uncertainty quadrant: "algorithmic advances," "predictive and analytics-oriented reporting," "full transparency and traceability," "evolution of sustainability reporting standards," "mandatory national and international regulations," "the role of regulatory and professional institutions," and "intra-organizational readiness and resistance."

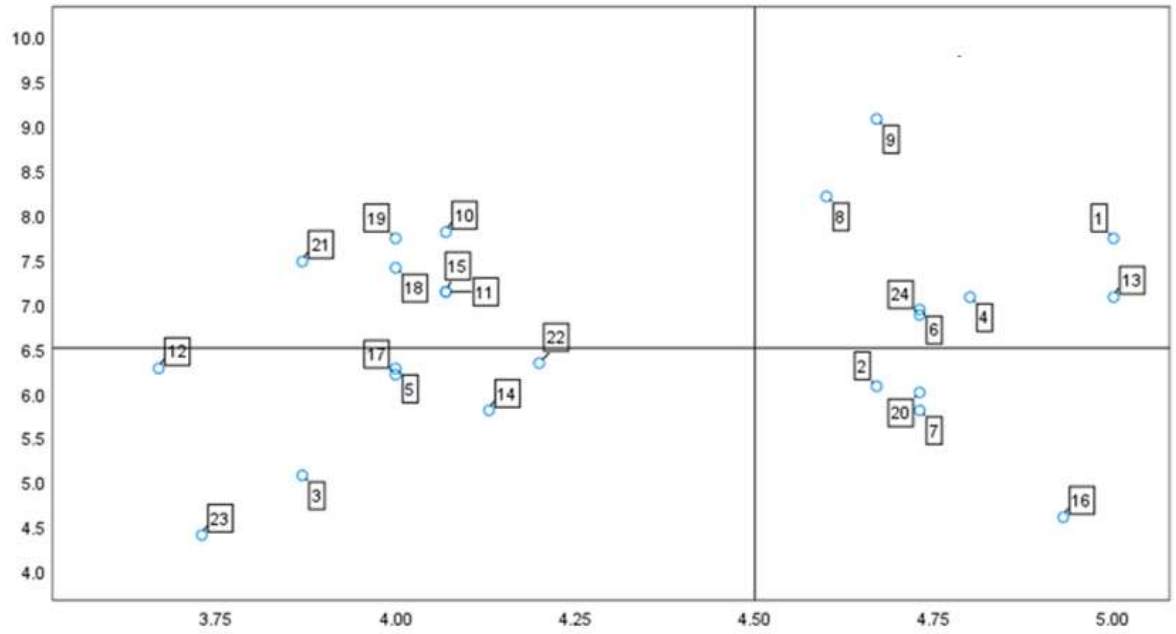


Figure 2. Positioning of the Drivers in the Importance–Uncertainty Matrix

Table 7. Key Drivers Based on Simultaneous Satisfaction of the Importance and Uncertainty Thresholds

Code	Driver	Category	Importance	Uncertainty
D01	Algorithmic advances	Technological	5.00	7.73
D04	Evolution of sustainability reporting standards	Legal	4.60	8.20
D05	Mandatory national and international regulations	Legal	4.67	9.07
D07	Role of regulatory and professional institutions	Political	5.00	7.07
D10	Predictive and analytics-oriented reporting	Technological	4.80	7.07
D12	Full transparency and traceability	Technological	4.73	6.93
D18	Intra-organizational readiness and resistance	Social	4.73	6.87

The selected set of drivers comprises three technological factors, two legal factors, one political factor, and one social factor. Within the technological dimension, algorithmic capacity, the analytical functionality of reports, and information traceability represent three distinct components of the transformation of reporting practices. Within the legal dimension, the evolution of standards and mandatory regulations were both assessed as highly important while also being characterized by uncertain trajectories of development. The role of regulatory and professional institutions reflects the dimension of professional guidance and oversight, whereas intra-organizational readiness and resistance incorporates the managerial and human aspects of transformation adoption among the selected factors.

None of the economic factors simultaneously met both thresholds; however, this finding does not imply that the economic dimension is unimportant. "Investor demand and sophistication" had a high importance score, but its uncertainty was below the threshold. "Access to capital and sustainability premiums" and "carbon pricing models and market mechanisms" both had uncertainty scores above the threshold, but their importance scores did not reach 4.5. Therefore, the selection output specifically represents the seven drivers characterized by simultaneously high importance and high uncertainty rather than a list of all important factors affecting sustainability reporting.

4. Discussion and Conclusion

The present study sought to identify, classify, and prioritize the drivers of AI-based sustainability reporting in Iran and to distinguish those drivers characterized by simultaneously high importance and high uncertainty. The Delphi process resulted in the retention of 24 drivers from an initial list of 36, while Kendall's coefficient of concordance increased from 0.322 in the first round to 0.546 in the third round, indicating a progressive convergence of expert judgments. The retained drivers were classified into technological, economic, legal, political, and social dimensions, with the technological dimension accounting for the largest share, followed by the economic and legal dimensions. This multidimensional distribution confirms that AI-based sustainability reporting should not be interpreted as a purely technological innovation. Rather, its development depends on the interaction of technological capability, institutional arrangements, regulatory pressures, economic incentives, stakeholder expectations, and organizational preparedness. This interpretation is consistent with previous sustainability-reporting research showing that disclosure practices emerge through the combined influence of internal characteristics, external pressures, governance mechanisms, and institutional contexts [1, 15, 16]. It is also compatible with the broader view of business sustainability as an integrated organizational process requiring alignment among strategy, governance, performance measurement, and stakeholder accountability [3, 4].

The technological dimension contained seven retained drivers and represented the largest category in the final classification. This finding is theoretically plausible because AI-based sustainability reporting fundamentally depends on data-processing capacity, algorithmic development, information systems, scalability, analytical capabilities, and mechanisms that ensure information quality. Among the technological drivers, algorithmic advances emerged as one of the most important factors and also met the uncertainty threshold for designation as a key driver. This finding reflects the rapid development of AI techniques and the growing potential of machine learning, natural language processing, predictive analytics, and automated data-processing systems to transform the way sustainability information is collected, interpreted, validated, and communicated. Previous research has similarly emphasized that artificial intelligence can enhance information-processing efficiency and improve the quality of reporting outputs by enabling more advanced analytical and automated procedures [9]. Likewise, the broader literature on AI for sustainability emphasizes the transformative potential of intelligent systems while highlighting that technological development remains dynamic and uncertain [12]. The prominence of algorithmic advances in the present findings therefore indicates that technological progress is not simply an enabling background condition but a central force shaping the future architecture of sustainability reporting.

Predictive and analytics-oriented reporting was also identified as a key driver, with both high importance and high uncertainty. This finding indicates that the future of sustainability reporting may increasingly shift away from static, retrospective disclosure toward forward-looking analytical systems. AI can potentially enable organizations to forecast environmental and social risks, identify trends in nonfinancial performance, detect anomalies, assess scenarios, and support strategic decision-making using sustainability data. The result is consistent with the

argument that digital transformation changes sustainability accounting from a conventional reporting function into a more integrated and analytically sophisticated management system [10, 11]. It also aligns with research emphasizing the need to integrate sustainability performance into core business processes rather than treating sustainability reports as stand-alone communication documents [4]. From this perspective, predictive reporting represents a movement toward decision-oriented sustainability intelligence, in which reporting becomes part of a continuous managerial information system.

Full transparency and traceability constituted the third technological driver among the seven key factors. This result highlights the increasing importance of creating verifiable information chains in AI-enabled reporting environments. As sustainability reporting becomes more data intensive and technologically mediated, stakeholders need confidence that disclosed information can be traced to its original source and that transformations applied to the data are transparent and auditable. Concerns about credibility are particularly important in contexts where greenwashing, selective disclosure, and opaque algorithms can undermine trust. The finding is therefore consistent with research showing that AI creates both opportunities to enhance sustainability transparency and risks of amplifying misleading disclosures if systems are not properly governed [14]. It is also compatible with the need for AI-specific disclosure frameworks capable of explaining how artificial intelligence is used, governed, and controlled within sustainability-reporting systems [13]. The identification of transparency and traceability as a key driver suggests that the value of AI in sustainability reporting depends not only on computational sophistication but also on whether the resulting information remains understandable, verifiable, and accountable.

The findings also highlighted the importance of security, privacy, and data integrity, although this driver did not simultaneously exceed both thresholds required for classification as a key driver. Its relatively high score nevertheless indicates that data governance is a major requirement for AI-based reporting. AI systems often depend on large volumes of data gathered from different organizational functions and external sources, and the integration of these datasets increases exposure to privacy risks, cybersecurity threats, data manipulation, and errors. The significance of this issue is implicit in the broader literature on digitalized sustainability reporting, which emphasizes the importance of reliable digital infrastructures and robust information systems [10, 11]. The result also reinforces the interpretation that technological capability alone does not guarantee reporting quality; technological systems must operate within governance structures capable of protecting the integrity and reliability of information.

The legal dimension was especially prominent because two of its drivers—evolution of sustainability reporting standards and mandatory national and international regulations—were among the seven key drivers and also exhibited the highest uncertainty scores. Mandatory national and international regulations had the highest uncertainty value of all drivers, while the evolution of sustainability reporting standards ranked second. This result suggests that experts perceived the legal-regulatory environment as both highly consequential and difficult to predict. Such an assessment is reasonable because sustainability-reporting requirements are evolving rapidly across jurisdictions, and organizations must respond to changing expectations regarding disclosure scope, materiality, assurance, comparability, and accountability. The result is strongly aligned with research showing that sustainability reporting is increasingly influenced by formal institutional requirements and by the progressive development of reporting and assurance frameworks [5]. Earlier studies also indicate that sustainability-reporting practices are shaped by external institutional pressures and regulatory conditions [1, 24]. In Iran, where sustainability reporting remains in a developing institutional stage, uncertainty surrounding future mandatory requirements may significantly affect organizational willingness to invest in advanced reporting technologies.

The high importance assigned to the evolution of sustainability reporting standards also reflects the central role of standardization in making AI-based reporting operational. AI systems require clear definitions, consistent indicators, structured data, and stable reporting rules if automated analysis is to produce comparable and meaningful outputs. The diversity of indicators historically used in sustainability reports has been widely documented, demonstrating the challenges created by heterogeneous reporting practices [2]. Standardization can therefore facilitate automation, comparability, machine readability, and assurance. At the same time, the uncertainty surrounding evolving standards means that organizations face strategic risks when designing technological systems around reporting frameworks that may change. The present result thus indicates a close interdependence between technological investment and regulatory development.

AI ethics and governance frameworks also received a relatively high uncertainty score, although their importance score did not reach the threshold required for inclusion among the seven key drivers. This pattern is noteworthy because it suggests that experts recognize ethical and governance issues as uncertain and potentially influential, even if they are not yet perceived as immediately critical as formal regulations and reporting standards. This finding is consistent with literature emphasizing that AI can generate challenges related to accountability, bias, explainability, privacy, and legitimacy [12]. It is also consistent with the argument that firms increasingly need systematic frameworks for disclosing and governing their use of artificial intelligence [13]. The distinction between formal regulation and ethical governance observed in the findings may reflect the fact that organizations often prioritize legally enforceable requirements over emerging normative expectations, especially in environments where AI governance frameworks are still evolving.

Within the political dimension, the role of regulatory and professional institutions emerged as a key driver with the maximum importance score of 5.00. This finding suggests that experts viewed professional bodies, regulators, accounting institutions, audit organizations, and related supervisory actors as central to the development of AI-based sustainability reporting. Such institutions can translate broad regulatory requirements into operational guidance, establish professional expectations, promote assurance practices, issue technical standards, and facilitate organizational capacity building. The result aligns with evidence that the development of sustainability reporting is often supported by institutional coordination and professional guidance rather than by individual corporate initiatives alone [24]. It also corresponds with research emphasizing the importance of governance structures in determining the quality of sustainability reporting [15]. In Iran, the role of regulatory and professional institutions may be particularly important because these bodies can bridge gaps between international sustainability-reporting developments and domestic organizational practice.

The social dimension contributed one key driver: intra-organizational readiness and resistance. Its inclusion among the high-importance/high-uncertainty factors shows that the successful adoption of AI-based sustainability reporting depends heavily on organizational acceptance, managerial commitment, employee skills, and the capacity to manage change. This finding is consistent with research demonstrating that sustainability reporting is closely linked to organizational change and that effective reporting processes require modifications to structures, routines, responsibilities, and information flows [7, 8]. Iranian studies have similarly shown that internal organizational factors influence the extent and quality of sustainability reporting [18], while organizational capabilities have been associated with social responsibility performance among listed firms [17]. The result therefore confirms that technological transformation cannot succeed without corresponding managerial and human transformation.

The importance of organizational readiness can also be interpreted through the broader relationship between work systems and employee adaptation. AI-based reporting may change professional roles, redefine responsibilities, and require closer cooperation among accounting, auditing, information technology, sustainability, and management functions. Such transformations can generate resistance if employees perceive technological change as threatening, poorly designed, or incompatible with established practices. The literature concerning workplace conditions and employee quality of work life underscores that organizational environments influence how individuals respond to structural and technological change [25]. Accordingly, investment in technology must be accompanied by training, communication, participation, and redesign of work processes if AI-enabled sustainability reporting is to be adopted effectively.

The economic dimension contained six retained drivers, yet none met both the importance and uncertainty thresholds simultaneously. This is an important finding because it does not imply that economic factors are unimportant; rather, it indicates that they occupy different positions in the importance–uncertainty space. Investor demand and sophistication had one of the highest importance scores but relatively low uncertainty. This suggests that experts regarded investor demand as a strong and relatively predictable force. Such a conclusion is consistent with the increasing relevance of sustainability information to capital-market participants and the broader integration of sustainability into corporate accountability and investment decision-making [3, 5]. Early adoption of Sustainable Development Goal reporting has also been associated with specific organizational characteristics and external expectations, supporting the idea that stakeholder demand can shape reporting behavior [6].

By contrast, access to capital and sustainability premiums, carbon pricing models and market mechanisms, and international competitiveness exhibited relatively high uncertainty but did not reach the importance threshold for designation as key drivers. These findings suggest that the economic environment may shape AI-based sustainability reporting indirectly and unevenly. For example, carbon pricing and market mechanisms may become highly influential if regulatory and financial systems evolve in that direction, but their present strategic relevance may differ across industries. Similarly, access to capital may increasingly depend on sustainability performance, yet this relationship may not currently be sufficiently institutionalized in all segments of the Iranian economy. The importance of ownership structures and corporate governance in Iranian sustainability disclosure provides further evidence that economic and governance incentives operate differently across firms [19, 20]. The results therefore support a differentiated interpretation of economic drivers rather than treating them as uniformly important.

The exclusion of 12 preliminary factors is also theoretically informative. Factors such as data integration capabilities, middleware maturity, real-time reporting, the role of universities, digital infrastructure readiness, and business cultural norms did not achieve the minimum acceptance threshold in the final Delphi round. These results should not be interpreted as evidence that such factors are irrelevant. Rather, they indicate that the expert panel considered them less central within the specific context and decision framework of this study. This distinction is consistent with the literature showing that determinants of sustainability reporting vary according to institutional environment, organizational characteristics, and stage of reporting development [1, 16]. It is also compatible with Iranian studies demonstrating that the relative importance of sustainability-reporting determinants is context dependent [21-23]. Thus, the results provide a context-specific prioritization rather than a universal hierarchy of determinants.

Overall, the findings suggest that the future development of AI-based sustainability reporting in Iran will be shaped primarily by the interaction of technological innovation, regulatory evolution, professional oversight, transparency requirements, and organizational readiness. The fact that three technological, two legal, one political,

and one social driver were identified as key factors reinforces the socio-technical nature of the transformation. AI-based reporting cannot be advanced solely through investment in algorithms or software; it also requires reporting standards, enforceable regulations, professional governance, credible information architectures, and organizational capacity for adoption. This integrated interpretation is consistent with the broader sustainability literature, which emphasizes that effective reporting emerges from the interaction of organizational systems, governance mechanisms, stakeholder demands, and institutional arrangements [3, 7, 15]. It also supports more recent arguments that digitalization and artificial intelligence can strengthen sustainability reporting only when technological innovations are embedded within appropriate accountability and governance structures [10, 13, 14].

This study has several limitations that should be considered when interpreting the findings. First, the Delphi panel consisted of 15 experts selected purposively and through snowball sampling; although this approach was appropriate for accessing specialized knowledge, the resulting judgments may not represent the views of all relevant stakeholders involved in sustainability reporting, including investors, regulators, technology providers, civil society organizations, and corporate executives from different industries. Second, the study focused specifically on the Iranian context, which limits the direct generalizability of the findings to countries with different regulatory, technological, economic, and institutional environments. Third, the assessment of importance and uncertainty relied on expert perceptions at a particular point in time, while both AI technologies and sustainability-reporting regulations are evolving rapidly. Fourth, the classification and prioritization procedures necessarily simplified complex interactions among the drivers, and the threshold-based selection of key factors may have excluded variables that are influential under particular organizational or industry conditions. Finally, no longitudinal organizational data were used to validate whether the identified drivers actually predict adoption intensity or reporting quality over time.

Future studies can extend the present findings in several directions. Larger and more heterogeneous expert panels should be used to compare the perspectives of accountants, auditors, sustainability managers, regulators, investors, technology specialists, and corporate executives. Comparative studies across industries may identify sector-specific differences in the importance of regulatory, technological, and economic drivers. Cross-country research could also examine whether the identified structure is unique to Iran or reflects broader patterns in emerging economies. Longitudinal research would be particularly valuable for assessing how the importance and uncertainty of the drivers change as sustainability regulations, AI capabilities, and capital-market expectations evolve. Future researchers may also apply structural modeling, fuzzy cognitive mapping, DEMATEL, interpretive structural modeling, or network analysis to examine causal relationships among the drivers in greater depth. Empirical studies based on firm-level data could test whether organizational readiness, regulatory pressure, technological capability, and professional oversight predict the actual adoption of AI-based sustainability-reporting systems and whether such adoption subsequently improves reporting quality, assurance, stakeholder trust, or organizational sustainability performance.

For practice, organizations should approach AI-based sustainability reporting as a coordinated transformation program rather than as an isolated information-technology project. Senior managers should establish cross-functional governance structures that connect accounting, auditing, sustainability, information technology, risk management, legal, and executive functions. Investment priorities should focus on algorithmic capability, data traceability, information integrity, and analytical reporting while simultaneously strengthening cybersecurity and internal controls. Organizations should monitor emerging sustainability-reporting standards and national and international regulatory requirements so that technological systems can be designed with sufficient flexibility to

accommodate future changes. Regulatory and professional institutions should develop practical implementation guidance, promote interoperability and data standards, and support professional training in AI-enabled sustainability reporting. Firms should also conduct readiness assessments before implementation, identify sources of employee resistance, provide targeted training, and clarify how human judgment will interact with automated systems. Pilot projects can be used to evaluate costs, benefits, risks, and data-quality requirements before enterprise-wide deployment. Finally, organizations should ensure that AI improves transparency and decision usefulness rather than merely increasing the volume or technological sophistication of sustainability disclosures.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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